BRIEFER ARTICLES

THE NATURE OF BALANCED SOLUTIONS

In his recent "Note on balanced solutions"[1] Professor LOEW criticizes some of my statements. The following reply is inspired solely by the desire to obviate if possible any misunderstanding regarding the nature of a balanced solution.

A balanced solution is defined by LOEB as one in which the toxic effects which each salt would have, were it alone present in solution, are inhibited by one or more antagonistic salts in the solution.

Professor LOEW objects to the term toxic as applied to calcium and potassium salts. His statement that I and a pupil claim to have discovered the poisonous action of potassium and calcium respectively is evidently due to a misapprehension. On the contrary, we treated them as fully accepted facts, and it was a surprise to us that he should call them in question. The poisonous action of a salt must be determined by comparing its effects with those of *pure* distilled water, or, in the case of strong solutions, with the effects of an isotonic balanced solution or an isotonic solution of an indifferent substance, if such can be found. In the absence of the facts needful for such a comparison, it is not possible to say whether the effects observed by him are to be regarded as toxic or not. At the concentration chiefly used in my experiments (.12 *M*) roots of wheat reached a length in KCl of 63^{mm}, in $CaCl_2$ of 84^{mm}, in an isotonic balanced solution of 360^{mm}, and in distilled water of 740^{mm}. I may add that for certain forms of Vaucheria KCl and $CaCl_2$ at the dilution of .001 *M* (or even less) may be toxic, inasmuch as they kill the algae in three or four days, while in distilled water or dilute sea water of a hundred times greater osmotic pressure, they remain alive for many weeks. For such forms the components of Knop's solution including the K and Ca, taken individually, would prove poisonous. But for such plants as wheat the concentration of Ca and K used in Knop's solution is too weak to be regarded as toxic.

Professor LOEW's designation of Knop's as a balanced solution seems, to say the least, very misleading. In a balanced solution the components are poisonous when taken separately. But Professor LOEW tells us that neither calcium nor potassium salts are to be regarded as poisonous. They are important constituents of Knop's solution. How then does he regard it as a balanced solution? Only it would seem (since here the

[1] BOT. GAZETTE 46:302. 1908.

toxicity of the anions is negligible) by supposing that the sole poisonous constituent is magnesium, whose toxic action is completely inhibited by the calcium present. But on this view it is clear that the potassium and iron are completely superfluous from the standpoint of a balanced solution. Knop added them for nutrient, not for balancing, purposes, nor is there reason to suppose that he was aware of antagonistic salt effects. At the concentrations at which he worked these effects are not at all evident with such flowering plants as were used in his experiments. Under these circumstances the discovery of antagonistic salt effects is very improbable. For most of the plants for which Knop's solution is employed at its ordinary concentration, it is not a balanced solution, because its individual components are not sufficiently toxic to require balancing.

That to Professor LOEW is due the very great credit of investigating the antagonistic action of magnesium and calcium, and of making clear its economic importance, is acknowledged by all. These and other investigations made by him in the difficult and obscure field of the function of the mineral salts are of the highest value. Together with the experiments of other investigators they have thrown much light on antagonistic action. Inasmuch, however, as Professor LOEW apparently does not believe in generalizing the principle of antagonistic action, as Professor LOEB has done in his theory of balanced solutions, but prefers to restrict it to the single case of Mg *vs.* Ca, I find myself quite unable to agree with him. In the course of a series of experiments on wheat I have found antagonism between each of the following pairs of salts:

NH_4 *vs.* Ca	NH_4 *vs.* Na	Mg *vs.* K	Na *vs.* Sr
K *vs.* Ca	NH_4 *vs.* K	Na *vs.* Ba	K *vs.* Sr
Na *vs.* Ca	Na *vs.* K	K *vs.* Ba	Mg *vs.* Sr
Mg *vs.* Ca			

One who has to deal with such a series of facts can hardly be expected to adopt a view which accounts for only one of these cases and ignores the rest, or explains them as due to the formation of double salts, particularly as such an explanation is wholly untenable in view of the facts of dissociation:—W. J. V. OSTERHOUT, *University of California, Berkeley.*